Outcomes Report of the final **Science-Policy Dialogue of the Food-Energy-Water Nexus Workshop:**
Securing Water-Energy-Food for the Nation's Future

November 4, 2022, Texas A&M University-San Antonio.

Workshop Synopsis
This workshop is the culmination of NSF funded project *INFEWS/T3: Decision Support for Water Stressed FEW Nexus Decisions (DS-WSND)* NSF Award Number:1739977. The project focused on water, energy, and food resources for sustainable resources management and used as case studies the regions of San Antonio, TX and Salton Sea Basin, CA. The project aimed to equip multi-sectoral stakeholders with models and decision support tools capable of evaluating the trade-offs and synergies associated with decisions made across food, energy, and water (FEW) systems in the two regions. An interdisciplinary team of hydrologists, agricultural economists, energy engineers, water engineers, agricultural experts and outreach specialists worked over five years, engaging with stakeholders from both regions throughout. The project outcomes include the development of innovative integrated FEW models and key recommendations for better coordinated management of the interconnected resources systems in water scarce regions. The Workshop Goals were to 1) share project outcomes with key regional stakeholders, 2) engage with decision makers and resource managers regarding challenges to and opportunities for coordinated management of the food-energy-water systems, and 3) create a platform for dialogue between scientists and decision makers with the goal of improved science – policy interactions.

The Workshop included introductory statements. ***Mirley Balasubramanya*****,** Chair, Department of Mathematical, Physical, and Engineering Sciences, College of Arts and Sciences, TAMU-San Antonio, who welcomed the attendees to TAMU-SA campus and addressed the relevance of the Urban University to serving the needs of local communities in primary resources management. ***Henry Fadamiro*****,** Associate Vice President for Research, Strategic Initiatives, Division of Research, TAMU-College Station spoke of the importance and priority of partnerships in addressing the WEF challenges for Texas and globally, noting that it is a key priority for TAMU to pursue the opportunities that lie ahead. ***Phyllis Viagran*****,** Councilwoman, City of San Antonio, spoke of the 'food desert' in the San Antonio region and asked how adopting a WEF approach can help resolve the issues of lack of access to food storage in the face of increasing food insecurity. The Councilwoman noted that work with the Food Policy Council of San Antonio has improved health issues related to the challenges and that they will use outcomes from this workshop in addressing the climate action plan for the region.

1. **Project overview and workshop introduction** were presented by co-PIs, ***Rabi Mohtar***, Department of Agricultural and Biological & Zachry Department of Civil & Environmental Engineering, and ***Bassel Daher**,* Texas A&M Energy Institute, TAMU-College Station.

Rabi Mohtar: Project Overview
The overarching goal of the Water-Energy-Food Nexus Initiative (WEFNI) is to expand the intellectual capacity and scope of Texas A&M's Water-Energy-Food Nexus community by i) developing analytics and best practices for policy and governance, ii) establishing a Nexus community of science and practice, and iii) identifying opportunities and gaps in current WEF nexus related research. The specific goal of WEFNI is to support the planning for WEF resources in San Antonio and the surrounding regions, as climate alters water supplies. This support will be through 1) facilitation of science-based policy by raising awareness among academia, society, government, and industry members; 2) encouraging holistic approaches to address the grand challenges and the sustainable development goals; and 3) identifying and responding to national and global opportunities in research, education, outreach, and policy implementation. The total duration of the

project was 5 years, 200 research and extension faculty from the Texas A&M System who comprise the TAMU Nexus community were engaged. Six subgroups were formed with expertise in data and modeling, water for energy, energy for water, water for food, governance and financing, and trade off analysis. The outcomes of this INFEWS project include data for integrative models, stakeholder engagement, energy modeling, agricultural modeling, hydrological modeling, coordinated and integrated nexus sector modeling, and nexus strategy analysis. Project outcomes also include publication of more than 60 journal articles, book chapters, and practice briefs. More than 25 state, national, and international conferences were conducted and over 30 invited presentations were produced.

Bassel Daher, challenges, barriers, goals, and expected outcomes.

Dr. Daher highlighted the need for cross-sectoral coordination and addressing barriers for improved integrative planning. He highlighted the low levels of communication between water, energy, and food stakeholders in the San Antonio region through presenting a social network map, the outcome of a survey sent to regional stakeholders. The results illustrated that the overall level of communication of water institutions with other water, energy, food, and crosscutting institutions is low (10%). However, most of this communication, when it exists, is happening between water sector stakeholders. Major barriers to communication include legal and procedural barriers due to institutional mandates and the lack of coordination mechanisms, financial barriers resulting from uncertainty of who will pay for the time pursuing increased communication, uniformity of language, different planning horizons (10 to 50 years) for the water, energy, and food sectors that result in ideological differences and create barriers, different value systems across sectors, competition between local, regional, global organizations and across industries lead to issues of confidentiality, silo mentality and lack of common goals for collaborative projects.

Workshop Expected Outcomes

- Knowledge gained regarding the challenges and opportunities for operationalizing WEF nexus solutions (mandates, coordination mechanisms/platforms).
- Knowledge gained about data and tools to support better decision making (models, decision support tools, technologies).
- Identified ways to improve evidence-based decision making (barriers, governance, financing, technologies, training, and capacity).

2. **Session 1- Resource Management and Practice Panel, Moderated by *Walter Den,*** Department of Mathematical, Physical, and Engineering Sciences, TAMU-San Antonio. Panelists included: ***Jeremy Mazur***, Senior Policy Advisor, Texas 2036, ***Steven Siebert,*** Interim Director of San Antonio Water System's Water Resources, ***Daniel Leskovar***, Director, TAMU AgriLife Center, Uvalde, and ***Faruque Hasan**,* Assistant Director, Texas A&M Energy Institute, TAMU College Station.

- ***Texas 2036, Jeremy Mazur***, *Senior Policy Advisor*

Texas 2036 addresses the development needs of the water and energy sectors in Texas and to prepare for the predicted extreme climatic events and increasing population. It is important to consider public awareness of the water and energy sectors in Texas. Over 70% of Texans express concern about extreme weather conditions such as droughts and floods. The prediction of severe drought means that some communities may not have access to water and 88% of Texas voters are worried about their water supplies during drought conditions. 82% of voters agreed to increase state investment to expand water supplies in Texas to better face future drought; 84% agreed to create a fund to update water infrastructure needs across the state. Concerns for the energy sector include 52% of voters who prefer energy expansion, including oil, gas, nuclear, wind, solar, geothermal, and new clean energy sources, and technologies. As the nation’s energy leader, 72% of voters agree to lead the nation’s energy expansion with new technologies that will contribute to the Texas economy with a cleaner form of energy.

- ***2022 Water Management Plan Introduction, Steven Siebert,*** *Interim Director, San Antonio Water System's WaterResources*

The San Antonio Water System (SAWS) is one of the nation's largest municipally owned utilities and serves over 2.0 million persons; its water management plan is the guiding document for SAWS to meet long term water needs of its customers. The plan is updated every five years, and focuses on population projections, water demands, conservation programs, goals, and current and future supplies of water in San Antonio. SAWS presented a 50-year water management plan focused on population demands, supply management, diversified water resources, conservation, climate change and regional partnerships. A primary goal is reducing water consumption to 88 gallons per capita per day by 2070. To achieve these goals, the program engaged with the community through public committees, stakeholder organizations, traditional and social media, a San Antonio water website, and in person engagement. The progress of the Water Management Plan is demonstrated in the per capita reduction of water use by 51% from 1982 to 2021 (225 gallons/day in 1982 to 111 gallons/day in 2021). To address the climate change impacts on water resources and ensure resiliency, SAWS introduced a hybrid drought scenario. Next steps of the project include continued community engagement and feedback on this plan to brief SAWS board and city council. A new draft plan will be presented for approval from SAWS.

- ***Securing Water-Energy-Food for the Nation's Future, Daniel Leskovar,*** *Director, TAMU AgriLife Center, Uvalde*

Texas' winter gardens make a high contribution to the economy of southwest Texas, including $622 million from irrigated agriculture and $685 million from livestock production. The winter gardens produce commodity crops, forages, high value fruits and vegetables, cattle, sheep, goats, and poultry. Some of the strengths include rechargeable water resources, excellent soil and water quality, mild winter climate, long seasons, use of efficient irrigation technologies, balanced crop rotation systems, and a solid, agriculture based regional economy with dynamic corridors from SA-Austin to Laredo. The aim of this project is to introduce new technologies to secure water energy and food for nation's future from the challenges faced by food systems including extreme weather, population growth, labor shortages, limited water availability, depletion of natural resources, supply chain disruption, etc. The use of micro irrigation technologies, controlled environment agriculture, hydroponics cultivations, selection of crop based on balance between water use, costs and profits are some of the practices adopted by growers in the winter garden region and South-Central Texas. Some studies were conducted in Uvalde on integrated water and crop management practices including the use of humic substances, microbial interactions and deficit irrigation on growth and yield performances of fruits and vegetables. Findings of the case study conducted to evaluate the performance of different irrigation technologies on the lettuce crop highlighted that hydroponic cultivation of lettuce results in higher yield, higher quality, and higher water use efficiency than LEPA (low energy precision application) irrigation and SDI (subsurface drip irrigation) lettuce cultivations. Controlled environmental agriculture and vertical farming provide optimum land use, year-round production, local fresh food production, water recycling, and reduced use of fossil fuels. These are identified as solutions to current and future problems related to food systems (decreased arable land and freshwater resources, increasing population, urbanization, and climate change).

- ***Texas Energy Portfolio, Faruque Hasan, Assistant Director, Texas A&M Energy Institute, TAMU College Station***

Energy portfolio in Texas has diversified over the last decades and produces more electricity than any other state. In 2021, Texas energy portfolio includes 43% of the nation's crude oil production, 25% of natural gas production and 26% of all US wind powered electricity production. According to Texas energy consumption by end use for 2020, the industrial sector, including refineries and petrochemical plants, accounts for more than half of state's energy consumption and 23% of the nation's total industrial sector energy use. The unexpected low temperatures of February 2021 froze infrastructure at energy facilities and urges attention to strengthening US energy resilience for future challenges through actions such as protecting power generation and fuel supplies, expanding the grids and its interconnections, rethinking market design and resource adequacy, creating multi-day energy storage systems, modernizing buildings, infrastructure, and technology. There is increasing attention to energy transition, especially renewable energy, and energy storage, which offer more economic growth through innovations like carbon capture, hydrogen fueled energy and geothermal power generation. The "Federal bipartisan Infrastructure Investment & Jobs Act" provides more opportunities for Texas energy expansion through initiating carbon capture technologies such as regional direct air carbon capture hubs, creating four regional clean hydrogen hubs, and enhancing electric grid reliability and resilience against extreme weather events and cyberattacks. Considering the future challenges in the Texas energy sector, further attention and action are required in areas including decarbonizing the energy supply chain, reducing methane emissions and flaring, balancing the water-energy-food environment nexus, advancing alternative energy technologies, advancing the hydrogen economy, next generation biofuels, process emissions including low carbon feedstock solutions, electricity market design and technologies, renewable generation and energy storage and circular economy for life cycle obligations, plastics and chemicals.

3. **Session 2 - Science Panel,** Moderated by ***Samuel Zapata,*** Department of Agricultural Economics, TAMU AgriLife Research Center, Weslaco. Panelists included: ***Bruce McCarl,*** Project PI, Department of Agricultural Economics, TAMU. ***Stratos Pistikopoulos,*** Texas A&M Energy Institute, ***Styliani Avraamidou,*** Chemical and Biological Engineering, U Wisconsin-Madison, ***Hoori Ajami, Dhanesh Yeganantham,*** Department of Environmental Sciences, U California Riverside, ***Ronald Green,*** Southwest Research Institute

- ***Bruce McCarl: Food Energy Water Nexus in Regional Modeling Study***

The aim of the study is to determine the optimal mix of agriculture, water, and energy project options to meet growing water and energy demand under the influence of climate change and population growth on sectorial actions and water/energy supply decisions. With the development of the analytical tool "Food-Energy-Water Integrated Regional Simulating Model" comprising 23 Nexus related variables applied to four major river basins in South-Central Texas (including the Edwards Aquifer and the city of San Antonio). The model design is based on 2020 data and analyses the effect of population growth (2030, 2050, 2070, 2090) and 16 climate change scenarios on project options for meeting growing water and energy demands. The modeling foundation estimates the cumulative capacity of new selected water projects in San Antonio that meets the population projection under the dry and wet climate change scenarios including irrigated land transferred to dryland and pasture under climate change and over time due to the water scarcity.

- ***Stratos Pistikopoulos*** *and* ***Styliani Avraamidou: Energy System Planning Under Energy-Water Nexus Considerations***

The main goal of the research was to develop a systematic methodology based on five different nexus connections for improvement and expansion of power generating systems and water treatment facilities in Region L. The study points out that capturing stochastic fluctuations of the water-energy parameters interconnecting sub-regions is essential for a realistic representation of energy and water demands. The EW-N Algebraic model was adapted to provide optimal solutions to minimize capital and operational costs before setting up any new water/energy sources and storage facilities, reaching planning decisions for expansion, scheduling decisions for operations (e.g., allocation of water and energy between sub-regions) and meeting demand constraints. Various parameters (e.g., cost data for components, hourly water availabilities and demands, hourly energy demands and prices, hourly wind, and solar availabilities) are considered for meeting economic objectives and scenario testing is used to obtain model outputs. This serves to integrate planning and scheduling decisions, overcome computational difficulties, and uncertainties related to climate and population.

- **Hoori Ajami** and **Dhanesh Yeganantham,** Department of Environmental Sciences, UC Riverside: **Improving Water Resources Management Under Change by Integrating Hydro-Economic Modeling Frameworks**

The study focused on a detailed water budget analysis aimed at the basin system and root-zone subsystem for effective water resource management of agroecosystems utilizing a semi-distributed hydrological modeling approach. The Soil & Water Assessment Tool (SWAT) was integrated with economic models for the Salton Sea basin, California and the Guadalupe, San Antonio, San Antonio-Nueces and Nueces watersheds, Texas. The key objectives of the study were to model hydrological processes (river flow) and agricultural production (crop yield), analyze potential impacts of water savings strategies like improvement in irrigation scheduling, crop selection and deficit irrigation and to run climate change scenarios for anticipation of future environmental and socioeconomic issues. It was suggested that complex and multiple drivers of hydrologic processes control crop yield and integrated hydro-economic models are valuable tools for decision making in such nature of studies.

- ***Ronald Green,*** Southwest Research Institute

The investigation of major and minor aquifers as sources of sustainable groundwater indicate that 7 of 18 aquifers are not sustainably pumped. There is no average ppt recorded so that this cannot be used for planning or design. The reality is that the greater the extremes and variability, the greater the uncertainty. The Edwards aquifer is not going to change much, so that water quality remains the greatest threat. Models are not going to tell us details but are sufficient for decision making – they provide Insights and not answers. We need 4-5 months of funding to support model and scenario development for the stakeholders. SWAT, GAMS are all available. We need to know more about what people want to change and we need the stakeholders to guide future use of the tools.

4. **Session 3 - Science-Policy Dialogue,** moderated by ***Rabi Mohtar*** and ***Bassel Daher,*** addressed three questions*:*
   - How might we best address the remaining barriers to implementing science-based decisions?
     - *Institutional; Knowledge dissemination; Personal awareness / capacity*
   - What mechanisms can be used to facilitate such dialogue?
     - *Digital Platforms; Community of Practice; Communication*
   - What is the future of system-based approaches to decision making?

Summary Reflections and the Way Forward

Computer models and tools play a crucial role in providing insights for decision makers in the water planning process, but they cannot be relied upon solely to provide answers. A multi-faceted approach is necessary to effectively inform policy making. This approach should involve both local engagement with policy makers, including judges and representatives, and the provision of accessible scientific information and policy briefs. It is important to recognize that lobbyists also have a role in decision-making and that science must remain objective by presenting facts, alternatives, and trade-offs. In addition to digital information dissemination, personal connections and community communication are crucial in finding and implementing solutions. These solutions must be driven by compensation, market, and incentives, and the implications of each alternative must be clearly communicated.

The greatest challenge facing the Edwards Aquifer is not water quantity, but water quality. A coordinated approach to water management and the development of a regional framework for nexus solutions are necessary to address this challenge. The establishment of governance mechanisms is crucial to prioritize regional welfare over individual welfare and address the high cost of pumping for irrigated agriculture in the Ogallala. Public perception can play a role in guiding national policy, but it is important to communicate the science in a way that is accessible and relevant to policy makers.

To mobilize political will for action, science and the public must be synchronized, and the science must be communicated in a manner relevant to policy makers. The communication of objective facts and a range of alternatives must be done through personal connections and community understanding. The governance must balance the "common good" and "compensation," ensuring that winners share the benefits with losers. Demonstrating solutions at scale will encourage their widespread adoption. In the end, it is important to remember that the provision of objective facts, alternatives, and trade-offs, through various communication channels, will help inform policy making and drive positive change.

The effective implementation of water planning solutions requires careful consideration of the messaging, the involvement of policy makers and the public, and the use of compensation and governance mechanisms. The scientific community must continue to provide objective facts and a family of alternatives and tradeoffs to ensure that policy is informed by science. Demonstrating these solutions at scale can help their adoption and implementation, ultimately leading to improved water management and sustainable use of resources.

Closing Remarks were offered by *Mirley Balasubramanya*